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LARRANAGA'S

PHOTO-PHONOGRAPH

BY

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JULIUS MAIER, Ph.D.

THE term Phonograph, or sound recorder, includes besides Edison's, Sumner Tainter's, Berliner's and the apparatus which is the subject of this pamphlet, a large number of instruments which, though they are not able to reproduce sound are capable of graphically representing it. It will be advisable for the better understanding of the following pages to say a few words on the nature of sound.

Bearing in mind that sound is and has for its origin, motion, we find that a vibrating body situated in an elastic medium like our atmosphere, becomes the central source of a peculiar form of action which is ever propagated outward. This is known as wave motion, and if the number of vibrations causing it be within certain limits, the wave motion becomes perceptible to the ear and is called a sound. Any change in the original vibrations will cause a change in the nature of the sound emitted. Thus, if their amplitude be increased, the sound becomes louder and can be heard at a greater distance, or, in other words, *intensity* is dependent on the extent of the vibrations.

Again, should the number of vibrations in equal portions of time be varied, the note will rise or fall in the musical scale; or, *pitch* depends on the number of vibrations occurring in a given time.

A third and, in this connection, more important characteristic of sound is that, while an unchanging *fundamental* tone is emitted, other and more rapid vibrations may accompany it, on the same principle that the surface of large ocean waves is covered with smaller and independent ripples. It is the accompaniment and predominance of certain of these *harmonics*,

as they are called, that gives to a note that peculiar property whereby it may be distinguished from another of equal intensity and pitch. This characteristic is called the *timbre* of the note.

The human voice is the most perfect all of musical instruments. Certain parts of its mechanism can, at will, be thrown into vibration, and these vibrations can be varied in amplitude and number at pleasure. Associated with the apparatus for effecting this is a hollow cavity, which serves, as does the resonant chamber of an organ pipe, to reinforce the sound. The shape of this cavity may be so varied that it will resound to variations of any pitch. By means of this latter power we are enabled to produce the vowel sounds.

Accompanying the original vibrations are others which are multiples of it, and it is by reinforcing one or more of these that the quality of each vowel is secured. Thus the forcible expulsion of air from the mouth may give rise to articulate speech or sounds, whose shadings and degrees of loudness vary with the number and pressure of the resulting impulses, and also with the degree of suddenness with which they commence and terminate.

So rapid are the vibrations of a body when emitting a sound that the eye and ear cannot discern all the phenomena which accompany them. This has led students of acoustics to devise means of representing graphically the movements which the sounding body undergoes; and it is through the study of these drawings that much of our knowledge of the nature of sound has been obtained.

One of the simplest ways of producing what is called the record of sound is to draw a vibrating tuning fork over a sheet of paper, so that a pencil attached to one prong of the fork shall leave behind it a waving line. With this crude arrangement the energy is wasted in overcoming friction and the fork soon comes to rest. To lessen the friction, paper covered with a layer of lampblack is employed and this paper was by *Duhamel* wrapped round a revolving cylinder the axis of which was a screw turning in a fixed nut, so that the cylinder advanced at each revolution through the distance

between two consecutive turns of the thread, thus preventing one portion of the record from being superplaced upon that which preceeds it.

An advance in the graphical reproduction of sound was made in 1857 by the French physicist Léon Scott, whose apparatus called *Phonautograph*, consists of a hollow chamber, made sufficiently large to respond to sound of the lowest audible pitch mounted before a cylinder, similar in construction to the one just mentioned. One end of this resonator is left open and the other is terminated by a ring on which is fixed an elastic membrane. The air within the resonator is easily thrown into vibration, which is shared by the membrane. The latter carries a stylus, which also participates in the motion, and records it upon the blackened paper. The human voice, the tones from musical instruments, and even the rumbling of distant thunder were thus graphically represented on paper.

Another most sensitive instrument for recording vocal impulses is the *Logograph*, invented by Barlow.

The pressure of the air in speaking is directed against a membrane, which vibrates and carries with it a delicate marker tracing a line on a travelling ribbon. The excursions of the tracer are great or small from the base line, which represents the quiet membrane, according to the force of the impulse and are prolonged according to the duration of the pressure produced by different articulate sounds varying greatly in length as well as in intensity; another great difference in them, also consists in the relative abruptness of the rising and falling inflections, which makes curves of various shapes. The smoothness or ruggedness of a sound has thus its own graphic character, independent both of its actual intensity and its length. The logograph consists of a small speaking trumpet, having an ordinary mouth piece connected to a tube, the other end of which is widened out and covered with a thin membrane of gold-beater's skin or gutta-percha. A spring presses slightly against the membrane and has a light arm of aluminium, which carries the marker, consisting of a small sable brush inserted in a glass tube containing a coloured liquid An endless strip of paper is caused to travel beneath the pencil and is marked with an

irregular curved line, the elevations and depressions of which correspond to the force, duration and other characteristics of the vocal impulses. The lines thus traced, exhibit remarkable uniformity when the same phrases are successively pronounced.

An even more delicate instrument for recording sonorous vibrations has been made by using the tympanum of the human ear as a logograph. The description of this apparatus would lead us too far, and we therefore proceed with our special task at hand.

The instruments thus far described, while able to produce records, undoubtedly correct, could go no further. The records thus made, suggested no way of reproducing the sound. Nor was this effected until Edison produced his talking phonograph. The way in which the invention was made is most interesting; it happened in this wise. During the Spring of 1877, Edison was trying a device for making a telegraph message, received on one line, automatically repeat itself along another line. This he did by embossing the Morse signals on the travelling paper instead of merely inking them, and then causing the paper to pass under the point of a stylus, which, by rising and falling in the indentations, opened and closed a sending key included in the circuit of the second line. In this way the received message transmitted itself further, without the aid of a telegraphist. Edison was running the cylinder which carried the embossed paper at a high speed one day, partly, as we are told, for amusement, and partly to test the rate at which the clerk could read a message. As the speed was raised, the paper gave out a humming, rythmic sound in passing under the stylus. The separate signals of the message could no longer be distinguished by the ear, and the instrument seemed to be speaking in a language of its own, resembling "human talk, heard indistinctly." Immediately it flashed on the inventor that if he could emboss the waves of speech upon the paper the words would be returned to him. To conceive was to execute, and it was but the work of an hour to provide a vibrating diaphragm or tympanum fitted with an indenting stylus, and adapt it to the apparatus. Paraffined paper was selected to receive the indentations, and substituted for

the Morse paper on the cylinder of the machine. On speaking to the tympanum, as the cylinder was revolved, a record of the vibrations was indented on the paper and by repassing this under the indenting point an imperfect reproduction of the sounds was heard. Edison saw at once that the problem of registering human speech, so that it could be repeated by mechanical means as often as might be desired, was solved.

Soon after this experiment a phonograph was constructed, in which a sheet of tinfoil was wrapped round a revolving barrel having a spiral groove cut on its surface to allow the point of the indenting stylus to sink into the yielding foil as it was thrown up and down by the vibrating tympanun. This apparatus—the first phonograph—was published to the world in 1878, and created a universal sensation. It is now in the South Kensington Museum to which it was presented by the inventor.

In this machine the barrel was fitted with a crank, and rotated by handle; a heavy fly-wheel was attached to it to give it uniformity of motion. A sheet of tinfoil formed the record, and the delivery could be heard by a room full of people. But articulation was sacrificed at the expense of loudness. It was as though a parrot or punchinello spoke, and sentences which were unexpected could not be understood. Clearly, if the phonograph were to become a practical instrument, it required to be much improved. Nevertheless this apparatus sufficiently demonstrated the feasibility of storing up and reproducing speech, music or other sounds. To show how striking were its effects, and how surprising even to scientific men, it may be mentioned that a certain *savant* on hearing it at the *séance* of the *Acádémie des Sciences* at Paris, protested that it was a fraud, a piece of trickery or ventriloquism, and would not be convinced. In the form thus described the phonograph remained for more than ten years, it was considered as little more than a scientific toy, fit for the lecture room or the curiosity shop. It could give no practical results because the articulation of reproduced speech was most imperfect, and certain sounds were entirely suppressed by it.

Some three or four years ago an improvement was

effected in the phonograph which again brought it prominently to the front and rendered it infinitely more efficient. This improvement consisted in the replacing of the tinfoil by a wax cylinder, and is due, not to Edison, but to Sumner Tainter who applied it to his *graphophone*. There is every reason to believe that this improvement caused Edison to again turn his attention to perfecting the phonograph, in which work he undoubtedly has followed Tainter's lead in employing a wax cylinder and a cutting stylus. A further important improvement was made by Edison in the working of the instrument by the employment of an electro-motor for obtaining uniform rotation, which is essential to correct reproduction of speech.

In its present improved form the phonograph consists of a box containing the silent electro-motor, which drives the machine, and supporting the works for printing and reproducing the sounds. Apart from the motive power which might, as in the graphophone, be supplied by foot, the apparatus is purely mechanical, the parts acting with smoothness and precision. These are, chiefly, a barrel or cylinder, on which the hollow wax is placed, a spindle which revolves the cylinder and wax, and two membranes, one of which receives the sounds and impresses them on the soft surface of the wax, while the other reproduces them. A governor regulates the movement of the spindle, and there are other ingenious devices for starting and stopping the apparatus.

To the membrane used for recording the sounds a mouthpiece is fixed for speaking into, while to the other membrane reproducing the sounds, a branched ear-piece is adapted, conveying them to the two ears of the listener. A separate box below the table contains the voltaic battery which actuates the electro-motor.

The *Graphophone*, which was developed between 1881 and 1887, differs in detail from the new phonograph and is worked by means of a treadle instead of a motor, but in all essential points it is similar to the Edison machine just described. There are two diaphragms, one for speaking into and the other for listening at, both provided with flexible tubes. The treadles worked by the feet, turn the rotating cylinder of wax

through the intervention of the speed regulator, and the cutting stylus projecting from under the middle of the vibrating diaphragm pares an undulating furrow in the wax and thus records the vibrations. Similarly, by means of the second diaphragm, of which the stylus traverses the record, the sounds are reproduced and conveyed to the ear by the hearing tube.

Before entering upon the description of the apparatus which forms the subject of this pamphlet, we have to mention a third instrument for the reproduction of speech, Berliner's *Grammophone*; we reserved this instrument for the last because it posseses certain points of resemblance with Mr. Larranaga's ingenious apparatus. The grammophone consists of a flat box into which the sound is conveyed by means of a funnel and a flexible tube. The box is closed in front by a membrane of specular gypsum on which, by means of a pin, a tracing stylus of elastic sheet copper with an iridium point, is fastened parallel to the surface of the membrane.

The recording surface consists of a circular, perfectly level and smooth zinc disc, resting on a brass plate in the centre of the apparatus, and rotated by a winch handle. When the plate revolves the stylus point describes a circular line on the zinc disc, but in order to prevent this line from returning within itself the arm carrying the stylus is placed on a sledge which advances very slowly towards the centre of the zinc disc. Thus, the traced line is transformed into a fine spiral which covers the recording surface to the length of several hundred miles.

But how is the writing to be traced on the zinc disc, since the tracing stylus must slide on it almost without friction, and an indentation of the writing in the hard metal seems to be altogether excluded by the principle of the apparatus?

This the inventor accomplishes by coating the zinc with an etching ground, which is so extraordinarily tender and soft that it covers the plate like a hardly visible film, and can be removed from it by the slightest touch. And yet, this etching ground is so dense and tough that it protects the metal completely against the action of strong acids.

This etching ground is produced by treating bees'-wax with benzine, whereby only certain portions of the wax are dissolved. This solution is poured on the plate which has previously been carefully cleaned; the benzine evaporates and the wax remains behind on the zinc as an exceedingly fine film.

If now, the grammophone is made to write on such a plate, the tracing stylus removes the wax from the plate and lays the metal bare. Soon, however, a difficulty presents itself; the dust particles suspended in the atmosphere fall on the plate, adhere to the point of the stylus and begin to trace characters of their own on the delicate film, whereby the sound record becomes indistinct and confused. To obviate this inconvenience, the plate is, during the reception of sound, constantly kept covered with a layer of alcohol, which drops on it from a flask placed above the apparatus. The alcohol keeps the dust particles suspended and constantly washes them off the plate, while the stylus remains the only master of the field and to the very last stroke traces the circles with the same sharpness, accuracy and correctness. When the reception of sound has been finished, the plate is taken off and washed with pure water. The writing traced on it is scarcely visible as yet, but it can be rendered visible, and, at the same time the necessary body for reproduction can be imparted to it by etching the zinc by chemical means. The etching liquid only attacks the places of the metal laid bare by the stylus, whilst the places protected by the thin wax coating remain unchanged. A new difficulty now presents itself; for the usual etching liquids of zinc act on the metal under generation of gas; now, each gas bubble prevents etching where it remains sticking to the metal, and the phonautogram (the record traced) becomes jagged and cracked, instead of being smooth and sharp. But here, too, the inventor knew how to get over the difficulty, *i.e.*, by the employment of a new etching liquid. He uses a solution containing ten per cent. of chromic acid which acts decisively, securely, and without generation of gas. Thus, the phonautogram becomes plainly visible on the zinc plate, in form of an indented line, or, in other words, a *sound plate* is formed. The reproduction by means of this sound plate is the usual one and requires no special description.

Having now given an account of the different contrivances hitherto employed in recording and reproducing speech, we pass on to the apparatus devised for this purpose by Mr. Luis Larranaga, of Lima, Peru. It occurred to Mr. Larranaga that in all the instruments used in recording speech, an imperfect fixed record of the human voice had hitherto been produced by attaching an indenting instrument or needle to a diaphragm caused to vibrate by the waves of sound set in motion by the human voice, and, if needs be, collected and reinforced by a resonance box. The indenting instrument or needle in a state of rest is in contact with, or in close proximity to a revolving cylinder, or other sound recorder and produces, at every vibration of the diaphragm, a more or less deep indentation on the soft material coating the cylinder. It is clear that for every forward movement of the membrane, a corresponding backwark oscillation must ensue, the membrane must return to its normal position, or practically so, after every oscillation, otherwise the result of the next succeeding oscillation would produce no perceptible effect on the material coating the cylinder. The records of the human voice hitherto obtained, Mr. Larranaga considers, only represent the forward oscillations of the diaphragm, while the corresponding backward motions, which naturally depend as much as the forward ones on the characteristic properties of the voice, are partly unrepresented in the tracings obtained on the cylinder. To this defect, Mr. Larranaga ascribes the imperfection of reproduction with the ordinary phonograph and proposes to remedy this defect, as far as this latter instrument is concerned, by fixing the stylus attached to the vibrating diaphragm to an articulated lever, carrying, at its lower extremity, a segmental cross piece, at either end of which a tracing pin is fixed at opposite corners. The forward vibrations of the diaphragm will now cause one of these tracing pins to be pressed against the cylinder, while the backward pulsations will have the same effect on the second tracing pin, and the tracings made on the cylinder will now represent the movements of the diaphragm in their entirety, they will be a faithful record of all the inflections of the human voice and will furnish a perfect reproduction of the sounds emitted before the membrane.

This, however, is rather in the way of a digression from Mr. Larranaga's actual invention; he deals with the difficulty just mentioned in an entirely different and much more ingenious way.

He causes the waves of sound to impinge against a sensitive flame, or against the diaphragm of a gas telephone having a lighted gas jet or flame, thereby varying the degree of its luminosity. By a suitable clockwork he then causes a bichromatised gelatine plate to travel in front of this flame, the action of which will decompose the bichromatised gelatine and produce, after development, on the part of the film exposed, a line indented more or less deeply, according to the luminosity of the flame.

The instrument certainly is one of the most beautiful illustrations of the equilibrium and the unity of natural forces—an equilibrium so nicely balanced that no change, however slight, can take place in one of them without producing a corresponding change in the other. We have here an instance of manifold conversions of energy, scarcely, if ever equalled, in the history of invention. To make the matter perfectly clear to the reader, let us enumerate these conversions:—

1.—The organs of speech produce sonorous vibrations, which, impinging upon the diaphragm, give rise to oscillations in the latter.

2.—The vibrations of the diaphragm cause an alternate increase or decrease of pressure in a gas chamber over the bottom of which the diaphragm is stretched.

3.—The luminosity of the flame fed by the gas contained in the chamber is increased or diminished according to the variations of pressure.

4.—The light of the gas jet is by means of a reflector and a lens thrown on a bichromatised gelatine plate.

5.—The bichromatised plate is decomposed more or less energetically, according to the variations of luminosity of the gas flame.

6.—By the action of the light the bichromatised gelatine is rendered insoluble.

7.—By a dissolving agent the undecomposed bichromatised gelatine is removed, *i. e.*, that portion of the coating of the plate which has not been acted on by the light, and a spiral line is left on the plate in more or less strong relief. This spiral curve may be pronounced a perfect record of the sounds emitted before the diaphragm.

8.—By the action of a stylus attached to a second diaphragm and moving over the spiral line traced on the plate, while the latter is being rotated, this diaphragm is thrown into vibration.

9.—By the vibrations of the second diaphragm the air is thrown into sonorous vibrations perceptible to the human ear.

Mechanical energy is thus converted into luminous energy, luminous energy is transmuted into chemical energy, and this latter reconverted into mechanical energy.

Having now stated the principles underlying Mr. Larranaga's invention we proceed to give a description of the apparatus itself, illustrated by the accompanying cuts.

Fig. 1 is a longitudinal section of the apparatus; Fig 2. is a section on the line $Y—Y^1$ of Fig 1. The same letters of reference are used to denote the same or corresponding parts in all the figures.

T is the mouth-piece connected by means of a flexible tube, T^2 with the resonance box A. Across the top of this box is fixed a vulcanite diaphragm D, which forms the bottom of the gas chamber G. The gas is passed into this chamber through the supply pipe G^2 at a steady moderate pressure, the pressure being regulated by any suitable mechanical means, and issues through the burner F^2, and when lighted gives a small steady flame, shown at F in the diagrams. As the waves of sound impinge against the diaphragm D it is thrown into vibration, thereby varying the pressure of the gas within the chamber G, and causing the light of the flame issuing at F to be increased or diminished in intensity.

The rays of light from the flame F are collected by the reflector R and are thrown on the lens L, by which they are focussed into the interior of the box O^2 having

a small aperture O. The reflector R and the lens L are capable of being adjusted as circumstances require. The box O^2 is attached to the partition B which divides the outer case B^2 into two parts. The partition B is held in place by guides $G—G^2$ and is kept away from the disc P by means of two cam levers W pivotted on each side of the outer case B^2, as shown in Fig. 2. On the side of the disc P nearest to the partition B the bichromatised gelatine plate is fixed, and contact between the box O^2 and the bichromatised plate is prevented by means of the cam levers W. By focussing the light into the box O^2 and carrying the said box forward until it nearly touches the bichromatised plate, as shown in Fig. 1, the beam of light, issuing from the small aperture O is prevented from losing any of its rays by divergence. That part of the outer case within which the bichromatised plate is placed, is made light proof, the only light admitted being that passing through the small aperture O; this precaution is necessary in order to prevent the decomposition of the bichromatised gelatine by any other than the light admitted through O.

The disc carrying the bichromatised plate receives a double motion, viz., it is rotated on its axis, and is at the same time caused to travel from the circumference to the centre, or *vice versa* across the aperture O of the box O^2, so that the indented line produced by the action of the beam of light on the bichromatised plate will be a spiral line. This double motion is produced by the following mechanism:—

The disc P is fast on the spindle H^2, which rotates in bearings H^3, carried by the slide-rest Q. H is a worm wheel keyed on the spindle H^2, and gearing with a worm K sliding on a feather on the transverse shaft K^2. This shaft K^2 is supported in bearings on the uprights U—U, and is provided at one end with a hand wheel H^1, by means of which it may be rotated when it is necessary to adjust the disc P by rotation. The other end of the shaft K^2 passes through the side of the outer case B^2 and is provided with a pulley M. driven by the strap M^2 from the hand wheel N.

On the disc spindle H^2 is keyed a toothed wheel E, gearing with a pinion on the parallel spindle P^2. On the spindle P^2 is keyed a worm I, which gears with

the worm wheel J. This worm wheel J is in the form of a nut on the screw shaft V which rotates in bearings on the uprights U—U and parallel with the shaft K^2. The end, V^2, of the screw shaft V is squared and protrudes partly through the side of the outer frame B, and over this squared end a key V may be placed, and the screw shaft thus rotated when it is desired to adjust the disc P from the centre to the circumference, or *vice versa* across the aperture O of box O^2.

The action of this mechanism is as follows:—

When the hand wheel N is rotated, the pulley M, shaft K^2, worm K and worm wheel H are also rotated. This causes the rotation of the spindle H^2 and disc P. At the same time the toothed wheel E rotates the pinion P^2, thus causing the rotation of the parallel spindle P^3, worm I, and worm wheel and nut J on the screwed shaft V. As the screw shaft V is normally stationary the nut J will travel along to the right or left according to the direction of the initial rotation of the wheel N. The worm wheel nut J carries the slide-rest Q, which carries the bearings for the spindles P^2 and H^2, therefore, as the nut J travels along the screw shaft V it will carry with it the whole of the gear, and will move the worm K on the shaft K^2. The slide-rest Q travels in a groove in the frame Z. When the screw shaft V is rotated by the key V the nut J will be made to travel longitudinally, without rotation on the screw shaft V, and the position of the disc P may be thus adjusted without rotation when such adjustment is required.

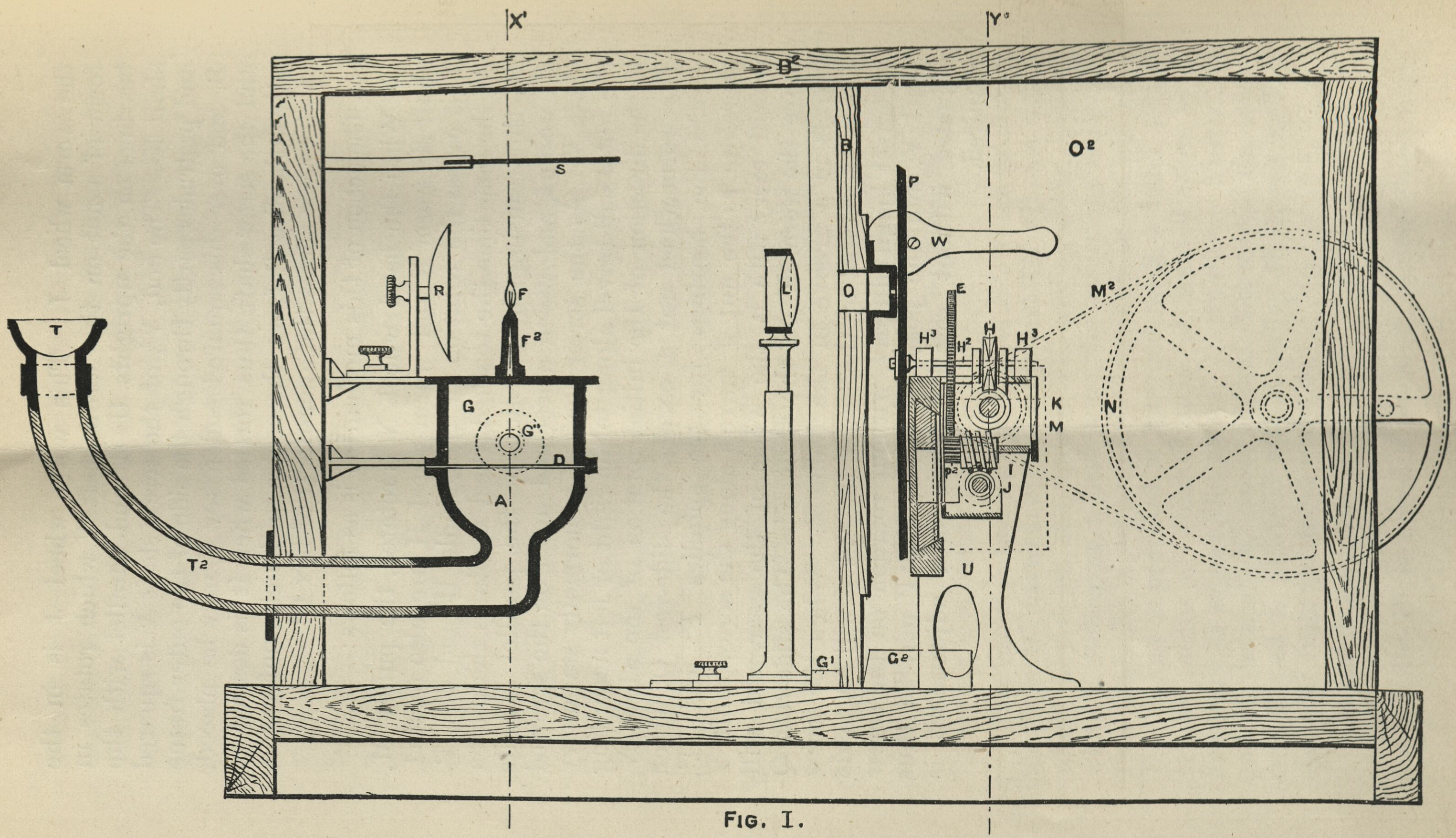

FIG. I.

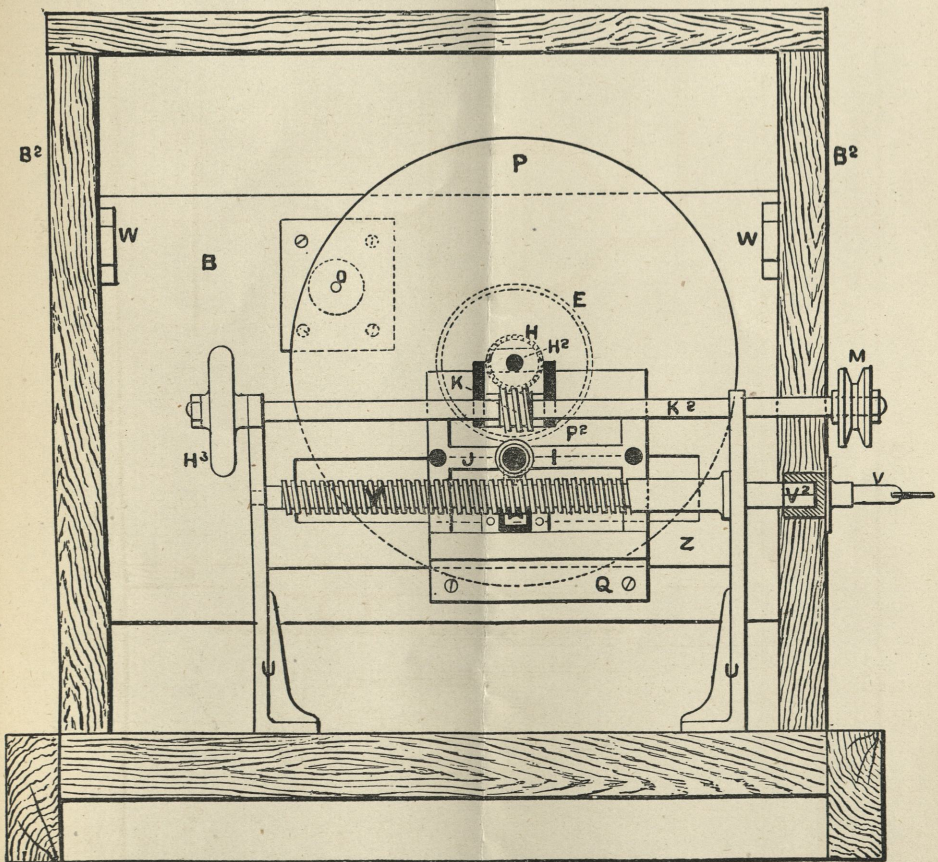

FIG. II.

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